Saskatchewan Research Council

Saskatchewan Research
Council

RECEIVED
NOV - 4 1982
LEGISLATIVE
LIBRARY

The House as a System

Energy Conservation Technology for Buildings

The House as a System

A Paper Presented at:
The 33rd Alaska Science Conference.
Appropriate Energy Technology for
Cold Regions.
Fairbanks, Alaska, September 17, 1982

SASK. LEGISLATIVE LIBRARY
JAN 11
REGINA

By:
D. Eyre
Saskatchewan Research Council
30 Campus Drive
Saskatoon, Sask. S7N 0X1

SRC Technical Report No. 136

October, 1982

SRC Publication No: E-825-52-B-82

ABSTRACT

The last major change in residential construction practice occurred in the 1930's, when there was a rapid growth in the use of insulation of various types. This created a number of new problems, and led to the first use of vapour barriers.

We are now in the process of another, and much greater, change in building practice. We are attacking all the components of the house on a broad front, in an attempt to make the house optimally energy-efficient. As in the 1930's, we are learning that the house is a balanced system made up of interacting components; when one component is changed it may sometimes have far-reaching, unforeseen consequences on the others.

In the author's view, energy-efficient house construction is proceeding generally in the right direction. However, if it is to continue in this direction, and if we are to avoid major errors, we must give high priority to looking at the house as a 'system'. We must try to identify or foresee the consequences of various changes, and devise ways of overcoming them.

This paper looks at the state of the art of energy-efficient house construction in Canada. It discusses some of the interaction problems that are now starting to emerge, and it looks at some of the ideas and techniques that have been devised to overcome them.Specific problem areas include furnaces, combustion air supply, air quality, structural integrity and structural moisture problems. A slide presentation will show techniques in new and retrofit construction.

CONTENTS

1.	INTRODUCTION	1
2.	A REVIEW OF PROBLEMS	4
	Attic Insulation	4
	Wall insulation	4
	Basement insulation	5
	Vapour barrier and sealing	5
	Ventilation	6
	Combustion air supply	7
	Furnaces	7
3.	SOLUTIONS FOR NEW HOUSING	8
4.	CONCLUSIONS	13
5.	REFERENCES	14
	Figure 1. The retrofit-ready design	9

When technological change is applied to a product - whether it be something like a car or a ball-point pen or a house - the process of change tends to follow a fairly well-charted route, in terms of time scale, market adoption and developmental problems. The size and frequency of the problems appear to be related to the scale of the technological change, and it also appears that the problems can be aggravated by attempts to accelerate the process of change - such as might happen in a competitive situation, or when tight deadlines are imposed.

These problems will occur even in the most controlled development program, of the sort that is possible in the automobile industry. Compared with this industry, the building industry is a highly uncontrolled, diffuse and de-centralized one. Therefore, when applying the major technological changes of energy conservation to the housing industry, it would be unrealistic to expect a smooth, problem-free transition.

In the author's view, residential energy conservation contains many of the elements that lead to developmental problems. The scale of the technological change is large, when seen against the general technical level in the industry. The process of change is being accelerated by government intervention - though one would not quarrel with the reasons for this intervention. The uncontrolled nature of the building industry, and the lack of mechanisms for technical development within the industry, make it difficult to achieve effective transfer of the technology to the industry.

Energy-efficient housing, of the sort that has been pioneered in the Saskatchewan Conservation House, the Copenhagen Zero Energy House and the prototypes built by Leger in Massachusetts, has been with us for five years or more. We are now into second and third generation designs, and we are also beginning to encounter some of the problems associated with these designs.

Most of the problems are the result of interactions: a significant change is applied to some feature of the house, and this is found to have some undesirable effect on another feature. This type of interaction was first encountered in the 1930's, when there was a rapid growth in the use of thermal insulation. This led to moisture problems, which were eventually solved by the development of vapour barrier technology. With energy-efficient housing, we are now encountering similar interactional problems over a wider range.

The majority of the problems can be overcome, or avoided, by respecting the fact that a house is a 'system' in which all the interacting components should be in balance. This system approach to energy-efficient housing was a major feature in the design of the Saskatchewan Conservation House. It was appreciated that super-insulation might aggravate moisture problems, which could be minimized by the use of air-vapour barrier techniques. In turn, the airtight construction that resulted from these techniques made it necessary to install a controlled ventilation system to ensure good air quality.

Experience has shown that this still a good approach, provided it is applied properly. So why all this talk about problems? The newly emerging problems fall into two categories:

- A range of subtle interactions that were not foreseen in the Saskatchewan Conservation House, or that were not relevant because the house had no combustion heating systems and no basement.

- A tendency, on the part of some builders and homeowners, to overlook the system approach and treat the various energy conservation features as options from which they can pick and choose, as in a supermarket.

Conventional house designs, though unsatisfactory from an energy conservation point of view, are very 'forgiving' in their operation. The leaky envelope ensures a large flow of air through the house. This generally

prevents hazardous air quality problems, and provides adequate air supply for the various combustion systems. Conversely, the high level of combustion induces the flow of cold air inwards through the house envelope, which inhibits the development of moisture problems in the envelope. Such houses, though inefficient, have a fairly well-balanced system which can tolerate some design errors - provided these are not too severe.

The energy-efficient house, on the other hand, is less forgiving. The various features are much more delicately in balance, and the house is not so tolerant of errors. It is therefore very important to approach energy-efficient design as a 'system'. This concept appears to be gaining ground in the technical community, but it has not yet found its way into the building industry - to any significant degree. It is hoped that this paper, which stresses the 'system' concept, will give builders and homeowners a better perspective on energy-efficient house design.

The following is a brief summary of some of the actual or suspected problems associated with energy-efficient housing, based on various research findings in Canada and the U.S.A.

Attic insulation

- Quality control: depth and density.
- Long term deterioration: settling, humidity effects.
- Chemical interactions of some insulations with metal truss gussets.
- Overheating on recessed ceiling lights.
- Overheating of electrical cables beyond rated temperature.
- Blockage of ventilation at soffits.
- Fire hazard due to piling of some insulation types against a hot flue or chimney.
- Potential for increased frost build-up if the ceiling vapour barrier is not adequately sealed.
- Possible enhancement of truss lift.
- Effective thermal resistance impaired by thermal convection or wind effect.

Wall insulation

- Effect on infiltration levels.
- Potential for increased moisture build-up.
- Corrosion of electricals.
- Electrical cable overheating.
- Pollutant effect of some insulation materials.
- Vapour barrier position during retrofit.
- Double vapour barrier during retrofit, or with use of low permeability sheathing.

- Deformation of double wall systems.
- Siding attachment through insulated sheathing.
- Compatibility of various multi-layer wall designs.
- Design of walls to ensure adequate moisture dispersal without impairment of insulation levels by wind effect.

Basement insulation

- Wall temperature cycling when basement is insulated on inside.
- Entrapment of vapour or seepage water behind vapour barrier, leading to rot of frame.
- Insulation and vapour barrier design at headers.
- Insulation attachment to outside of basement.
- Hydrostatic loading when porous insulation is attached to outside of basement.
- Protection of insulation above grade.
- Protection of insulation against soil interactions.
- Deeper frost penetration, perhaps to the footings and weeping tile system.
- Aggravated soil activity due to greater thermal cycling.
- Difficulty of insulating basement floor.
- Curing of basement floor concrete over insulation or vapour/moisture barrier.

Vapour barrier and sealing

- Lower level of air change leads to air quality problems (odour, humidity, pollutant build-up).
- Long-term stability of vapour barrier construction and material.
- Possible harmful chemicals emitted by some caulks and sealants.

- Combustion air supply problems induced by airtight construction.

- Impaired air circulation, induced by airtight construction and insulation. This leads to stale air problems in some parts of the house.

- Quality control of air-vapour barrier installation.

- Re-appraisal of the actual overall energy-efficiency of the air-vapour barrier, taking into account the ventilation and combustion air supplies that are made necessary by this practice.

- The role of the air-vapour barrier in control of moisture movement.

Ventilation

- The necessity of a controlled ventilation system in an airtight house.

- Development and research needed to come up with appropriate ventilation system designs.

- Difficulty of connecting ventilation systems to existing air-handling systems in retrofit.

- Location of exhaust and inlet vents to eliminate wind loading, cross-flow and interaction with gas connections.

- Neutral pressure plane effects arising from location of vents, with potential for aggravating moisture problems.

- Effectiveness of existing air circulation systems and designs, in reaching all parts of the house.

- Pressure fields set up by forced ventilation systems.

- Heat exchangers: cost, level of development, operational problems, installation, pollution.

- Correct treatment of dryer exhaust systems.

- Special ventilation needs for handling high concentrations of some pollutants (radon, formaldehyde).

Combustion air supply

- Adequacy of air supply.
- Desirability or undesirability of using ventilation system as air supply.
- Interaction of furnaces with open fires, stoves, etc. in an airtight house.
- Effectiveness and side effects of furnace rooms.
- Wind loading effects.

Furnaces

- Effects of oversizing, induced by retrofit of house (seasonal efficiency, flue icing).
- Problems with installing energy-efficient furnaces and electrical furnaces in poorly-sealed houses.
- Quality control of installation, with attention to control systems (thermostat, anticipator).
- Limitations on effectiveness of automatic dampers (interaction with domestic hot water heater).
- Limitations and permissible modifications of furnace units.

The Saskatchewan Conservation House was one of the first examples of the super-energy-efficient design. It is based on a system approach that incorporates four basic principles:

- High levels of insulation.
- Airtight construction.
- Controlled air management system.
- Passive solar design.

These concepts have now been adopted in a large number of second and third generation designs across Canada and in the U.S.A. The concepts are sound, and the main problem is to make sure that builders understand these concepts and the necessity for a system approach. A publication on air-vapour barrier construction (1) and an audio-visual presentation on super-energy-efficient housing (2) are helping to promote the technology in the building industry in Canada.

Saskatchewan Research Council has now progressed beyond the super-energy-efficient design, and is looking at ways of achieving high levels of energy conservation at low cost - in recognition of the current affordability problems that are generally threatening the housing industry. This new design has been called the 'retrofit-ready' house, since it concentrates on those features that will be difficult or costly to retrofit at a later date, and leaves the home owner to upgrade the remaining features at his leisure. The design is a carefully evolved package that goes a long way towards overcoming most of the known interactional problems. It has evolved, in part, from the Home Energy Loan Program standards, which Saskatchewan Research Council helped to develop for the Saskatchewan provincial government.

The main constructional features of the retrofit-ready house are shown in figure 1. The following numbered items refer to the labels in the figure:

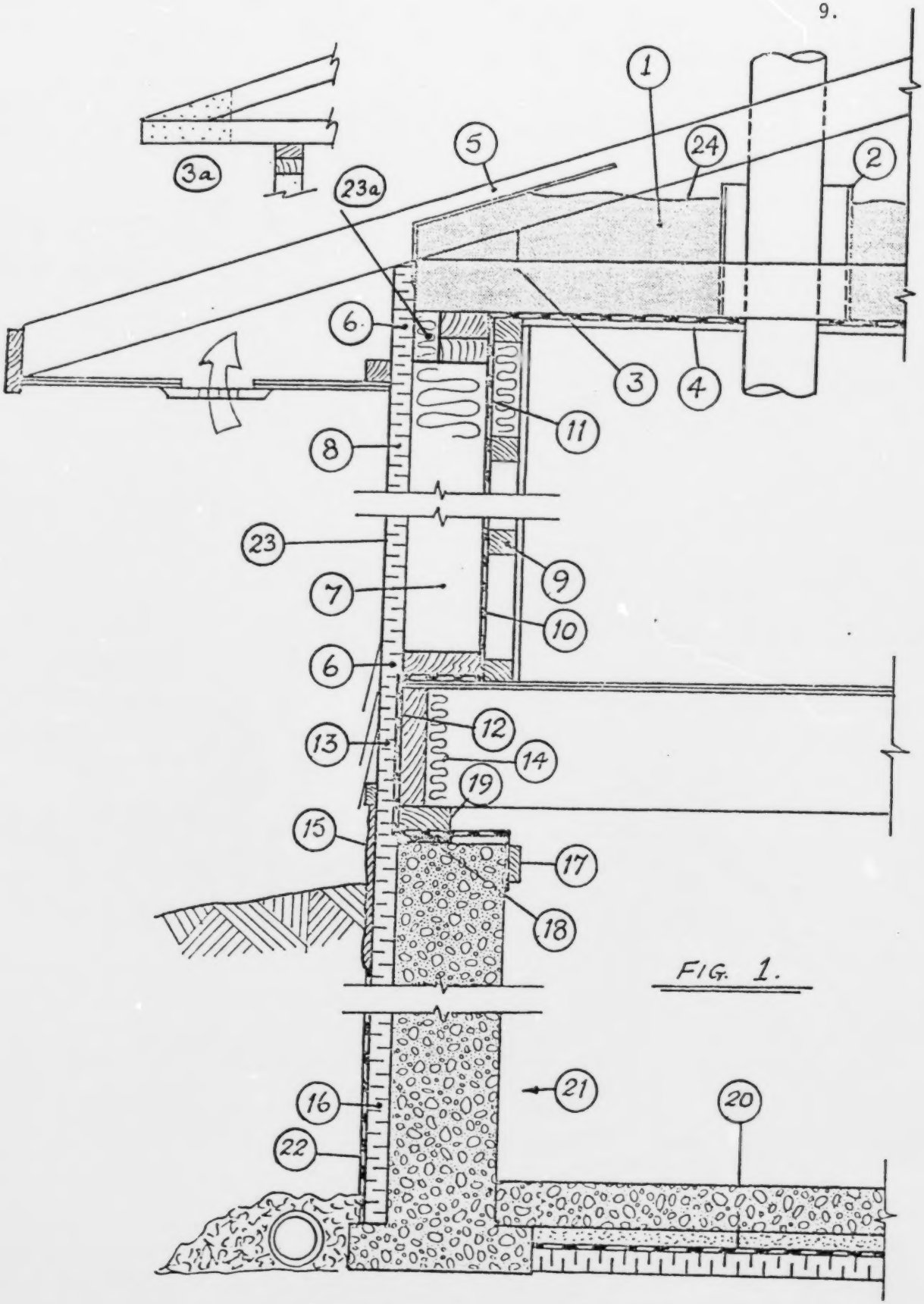

FIG. 1.

1. Ceiling insulation level R20 or more, at home owner's discretion. This can easily be added to at a later date, with correct built-in features.

2. Insulation stop around flue and attic hatch is at least 24" high to accommodate more insulation. Attic hatch should be on outside wall of attic for preference.

3. High hip truss to allow extra insulation over top of exterior wall, or use cantilever truss design as shown in 3a.

4. Ceiling plasterboard is 5/8" thick to bear extra insulation load.

5. Adequate soffit ventilation paths as a fail-safe, with insulation stops high enough to contain later additions of insulation. Note that over-ventilation should also be avoided.

6. Thermal bridging at top and bottom plates is reduced by rigid insulation sheathing.

7. Basic wall structure is 2 x 6 stud on 16" centres. Many builders find this easy to work with.

8. Exterior insulated sheathing is a desirable option. It prevents dewpoint problems on the warm face of the 2 x 6 studs. Thickness should not exceed 1.5", otherwise the nailing attachment of the siding will be weakened.

9. The strapped wall allows the addition of another R8 of batt insulation, and allows the location of the vapour barrier in a set-back position, where it will suffer less damage from electrical and drywall installation work (2 x 3 straps on edge).

10. The vapour barrier is continuous and is constructed to high standards of airtightness.

11. Condensation can occur on the warm side of the vapour barrier where it passes close to the 2 x 6 studs. The exterior insulated sheathing prevents this.

12. Vapour barrier is continuous around header.

13. There should always be some insulation outside the header, otherwise condensation will occur at the vapour barrier.

14. Insulation level inside vapour barrier should be less than half insulation level outside, otherwise dewpoint location will be inside vapour barrier and condensation will occur.

15. Insulation above grade is protected with parge on mesh, secured to concrete with mesh nails through insulation.

16. Rigid insulation carried to footing. Recommended thickness of 1.5" allows rigid insulation to be carried right down exterior wall without any jogs in the wall line. Top of insulation is secured with mesh nails; botton is secured with backfill.

17. Vapour barrier is carried to top of concrete foundation wall, caulked to concrete and fixed in place with nailing strip. This strip is used as a starting point for basement vapour barrier, if the foundation wall is framed and insulated at a later stage.

18. Felt or foam strip under vapour barrier prevents penetration by concrete.

19. Sill plate over vapour barrier prevents damage during floor joist installation.

20. Basement floor should preferably be insulated and provided with moisture barrier. Care is needed to avoid damage to these during concrete pouring. A layer of compacted sand gives protection, and assists the curing of the concrete

21. It is preferable to insulate the concrete on the outside where possible. This protects the concrete against thermal cycling, and allows the wall to act as a thermal storage medium. The interior should not be insulated and vapour barriered until the concrete has cured for six months, and then any cracks or seepage points must be repaired before insulation. When water enters the basement through

the foundation wall, it has no way of escaping if a vapour barrier is installed. The build-up of water can lead to rot of the wood frame. Therefore, the vapour barrier should not be installed until seepage is corrected and curing is complete.

22. A slip-coat of polyethylene should be attached on the outside of the rigid insulation to prevent lift-off or other damage resulting from soil reaction.

23. Whatever sheathing is used on the wall, it is essential to allow the wall to dissipate any excess moisture. If the wall is sheathed with a low-permeability material such as styrofoam SM, it is bad practice to seal the joints between the sheets. The wall must be allowed to breathe, but at the same time the wind movement through the wall must be kept to a minimum. Detail 23a shows one way of achieving a good moisture dissipation path. The double top plate is made of 2 x 4's, and the gap is filled with batt insulation. This allows moisture to dissipate into the attic, and it also reduces thermal bridging through the top plates.

24. A covering of olefin-spun paper on top of the insulation will potentially inhibit the impairment of the insulation by wind effect, and at the same time this will be porous enough to allow the passage of moisture. The technique is currently being studied, and its effectiveness has not yet been established.

Cost analysis shows that this design can be one of the most cost-effective options in some circumstances. Its low incremental cost makes it a good option at a time when affordability is a major issue in the building industry.

Experience with energy-efficient housing over the last five years has shown that a number of problems can arise from interactions of the various components and features. This means that energy conservation options cannot be selected according to the fancy of the home owner or builder, but have to be selected in the light of how they will interact with each other. The house design must therefore be evolved as a system or package, that is suited to its environment.

Such system designs are now starting to emerge, but there is still a lack of understanding of these systems in the building industry at large. This problem can be overcome only by better technology transfer to the building industry. The industry, for its part, must be prepared to make some effort to understand the new designs and concepts, if serious problems are to be avoided.

The housing industry in Canada, and to a lesser extent in the U.S.A., is currently facing problems due to the combined effects of recession and high mortgage rates. Affordability has become a general problem, and the energy-efficient house, with its extra capital cost, is particularly threatened. A more moderate approach to energy-efficient design, with a matching concern for incremental costs and structural integrity, would appear to be the most marketable option at the present time.

1. Eyre, D and Jennings, D. Air-Vapour Barriers Published and distributed by Energy Demand Branch. Energy, Mines and Resources. Ottawa.

2. Canada Mortgage and Housing Corporation. Envelope Construction of Energy-Efficient Housing. Details available through CMHC, National Office, Montreal Road, Ottawa.